Gravity-Fill Polymer Crack Sealers

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Cracking in bridge deck concrete is a serious problem. Cracks allow the direct infiltration of water and chloride ion and the carbonation of the walls of the crack, causing the reinforcing steel to corrode. Gravity-fill polymer crack sealers consist of two or more low-viscosity liquid monomer or polymer components that can be mixed and poured directly over a cracked surface. The monomer or polymer fills the cracks and hardens into polymer. The laboratory evaluation of three two-component epoxies, a three-component high-molecular-weight methacrylate, and a two-component polyurethane is described. Tests included measurements of the flexural strengths and freeze-thaw durabilities of repaired beams and the gel times and penetration abilities of the sealers. The five sealers were evaluated with respect to the effects of temperature and crack width on the quality of the repair, cost, ease of application, safety, appearance, and odor. The gravity-fill polymer crack sealers completely penetrated 0.2-mm-wide cracks, restored >100 percent of the original flexural strengths of the beams, had satisfactory freeze-thaw durabilities, and had gel times that decreased as the temperature increased. The laboratory tests suggest that all five gravity-fill polymer crack sealers can adequately seal cracks in bridge deck concrete.

Cracking in bridge deck concrete is a serious problem because cracks allow the direct infiltration of water and chloride ion and the carbonation of the walls of the crack. The presence of water and chloride ion and the low pH of carbonated concrete can cause the reinforcing steel to corrode. Gravity-fill polymer crack sealers can be used to fill and seal cracks and thereby extend the life of a bridge deck.

Gravity-fill polymer crack sealers consist of two or more low-viscosity liquid monomer or polymer components that can be mixed and poured directly over a cracked surface. The monomer or polymer fills the cracks and hardens into polymer that seals the cracks, bonds to the crack walls, and restores a percentage of the flexural strength of the original concrete. The repair can be completed within a short time because the only preparation necessary is to blast the crack clean with compressed air and because polymers that cure in minutes or several hours can be selected.

This paper describes the laboratory evaluation of three two-component epoxies (E1, E2, E3), a three-component high-molecular-weight methacrylate (HMWM), and a two-component polyurethane (U) with the properties given in Table 1. Tests included measurements of the flexural strengths and freeze-thaw durabilities of repaired beams and the gel times and the penetration abilities of the sealers. In addition, the five sealers were evaluated with respect to the effects of temperature and crack width on the quality of the repair, cost, ease of application, safety, appearance, and odor (*1*).

FLEXURE TESTS

The objectives of the flexural tests were to determine (a) the effect of crack width on sealer performance, (b) the percentage of the original flexural strength restored by the sealer, and (c) the type of failure (concrete, bond, or polymer). All tests were run at room temperature in a well-ventilated area following the safety precautions outlined by each manufacturer.

Sixty unreinforced portland cement concrete beams 7.6 × 10.2 × 27.9 cm (3 × 4 × 11 in.) (Table 2) approximately 6 months old were tested to failure by using three-point flexural loading (ASTM C78-84), and the ultimate strengths were recorded and are reported as the initial flexural strengths (Table 3). At approximately 2 weeks after the flexural tests the failed beams were prepared for crack sealing as follows.

To maintain cracks of known widths, wire spacers with diameters of 0.2, 0.5, 0.8, and 1 mm were used. The wires were cut into sections of approximately 3.2, 1.9, 1.3 and 1.0 cm (1.25, 0.75, 0.5, and 0.375 in.) in length, respectively. Four pieces of wire were then bent into an L-shape and were attached with duct tape to two outside faces of each cracked beam. Three beams were prepared to receive each product for each crack width. To secure the beams for polymer application the beams were placed in a specially designed jig to hold the sections together under a constant force of a torque screw. The bottoms and sides of the cracked sections were covered with duct tape to prevent leaking.

The polymer was mixed as specified by the material supplier and was poured over the cracks until a pool of polymer remained over the crack. Because of leakage and long penetration times the cracks typically needed to be retreated several times to completely fill the crack.

After 24 hr the beams were removed from the jig. If leaking caused the beams to stick to the jig they were loosened with a hammer and chisel. One week later excess polymer was removed from the exterior of the beams with a wire brush. The repaired beams were stored in the laboratory.

Two weeks after the cracks were sealed the repaired beams were tested again in flexure (ASTM 78-84). The results are reported in Table 3 as final flexural strengths.

Each beam was examined to determine the percentage of the new crack that failed in the concrete, bond, or polymer. Although most beams fail by a combination of failures in the three types the vast majority of the failure area was in the concrete.

The crack sections were sawed perpendicular to the plane of the cracks into three sections, exposing four interior surfaces showing the penetration of the sealers and the failure type inside the beam. Inspection of the sawed sections revealed that all of the polymers penetrated and filled the entire depths of the cracks, including the smallest crack width of 0.2 mm, and that wire spacers maintained constant crack widths.

The results based on the average of flexural tests on three beams are summarized in Table 3. All five polymers performed well by meeting the two desirable criteria of crack sealer materials: sealing the cracks and restoring the flexural strength of the concrete.

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TABLE 1 Properties of Crack Sealer Products Tested[a]

Products	Cost $/liter ($/gal.)	Mix Ratios (By Volume)	Viscosity at 23° C, cps [b]	Tensile Strength MPa (psi)	Elongation (%)	Odor
U	18-24 [c] (67-90)	A:1 B:1	A:12 B:16	31 (4500)	<10 (ASTM D412)	Almost none
E1	5 (18)	A:2 B:1	175-250	48 (7000)	1.9 (ASTM D638)	Stinky
E2	21 (80)	A:2 B:1	200-230	22 (3250)	37.5 (ASTM D638)	Mild
E3	9-13 [c] (33-50)	A:3.5, B:1 Weight: A:80% B:20%	300-500	29 (4247)	9.9 (ASTM D638)	Stinky
HMWM	11 (40)	A:1.0 B:0.02 C:0.04-0.08	<100	>10 (>1500)	>30 (ASTM D638)	Extremely pungent

[a] Based on product literature and personal communications with product suppliers.

[b] ASTM D2393.

[c] Lower price represents bulk rates.

Table 3 shows that under controlled laboratory conditions all five polymers on average restored 100 percent or more of the original flexure strength. It is unlikely that such high ratios would be achieved in the field because of carbonation, dirt, debris and other contaminants in the cracks. The higher final flexural strengths can be attributed to the different positions of the beams on the test machine or to the fact that when the initial crack was repaired the next crack developed at a higher flexural strength (*2*). Figure 1, a plot of the ratio of the final (*F*) and the initial (*I*) flexural strength versus crack width, illustrates the trend that as the crack width increases *F*/*I* decreases for all of the polymers. This trend implies that the polymers act more like adhesives in the narrow cracks and more like low-modulus concretes in the wider cracks.

The majority of the beams recracked in the concrete away from the initial crack site, indicating a strong bond between the polymer and concrete. Figure 2 illustrates the percentage of the new crack resulting from concrete, bond, or polymer failure. Examination of the crack face of the beams repaired with HMWM, E1, and E3 that failed at the initial crack site revealed that the new crack resulted almost entirely from a failure in the concrete. A very small percentage of the new crack was due to failure of the bond, and only a few beams showed an even smaller percentage of failure in the polymer. Several of the beams repaired with U and E2 had significantly higher percentages of bond failure, although E2 achieved one of the high *F*/*I* values. The majority of beams treated with E2 failed almost completely in the concrete; however, when failure did occur at the bond it comprised a very high percentage of the new crack, increasing the average percent bond failure. A plot of percent bond failure versus crack width showed that crack width has a minimal effect on percent bond failure except with U, in which the relationship seems to be direct.

FREEZE-THAW TESTS

The objective of the freeze-thaw tests was to determine the durability of the polymer crack repairs when they were subjected to ASTM C666 Procedure A.

TABLE 2 Concrete Mixture Proportions

	lb/yd^3	kg/m^3
Cement Type II Portland	635	375
Coarse Aggregate	1,897	1,119
Granite, specific gravity = 2.83		
Unit weight = 1,646 kg/m^3 (103.3 lbs/ft^3)		
Fine Aggregate		
Silica sand	1,077	635
Specific gravity = 2.58		
Fineness modulus = 2.70		
Water	286	169
Air = 6.5%	0	0

28-day compressive strength = 39 MPa (5,680 psi)

Fifteen beams that were 7.6 × 10.2 × 40.6 cm (3 × 4 × 16 in.) (Table 2) were prepared and tested in flexure the same way as described for the flexural tests, except only one beam was used for each crack width tested (0.2, 0.5, and 1.0 mm), and no beams with 0.8-mm cracks were prepared. The repaired beams were placed in the freeze-thaw test machine 2 weeks after the repairs were complete. Over a period of 8 weeks the beams were run through 480 rapid cycles of freezing and thawing, following ASTM C666 Procedure A modified by the addition of 2 percent NaCl to the water. Typically, beams are only subjected to 300 cycles, but the beams appeared to be performing so well at 300 cycles that the test was continued for 480 cycles.

Following the 480 cycles of freezing and thawing the beams were tested to failure by using the three-point flexural loading (ASTM C78-84), and the results were recorded and are reported in Table 4, along with the results obtained before repairing the beams.

It is obvious from a comparison of the flexural strength ratios given in Tables 3 and 4 that the freeze-thaw cycling caused significant reductions in the flexural strengths of the repair beams. E1 maintained the highest ratio of flexural strength of 71 percent, whereas U dropped to the lowest ratio of 12 percent as a result of the freeze-thaw testing. A plot of the flexural strength ratio versus crack width showed the same trend as that for beams tested without freeze-thaw cycling: as crack width increases, *F/I* decreases.

It is apparent from a comparison of the failure type results presented in Tables 3 and 4 that although the majority of failures again occurred in the old concrete, the percent bond failure significantly increased as a result of the freeze-thaw testing for U, E1, and E3. For E2 and HMWM the percent bond failure did not increase as a result of freeze-thaw testing. U experienced 100 percent bond failure for all crack widths following freeze-thaw testing.

TEMPERATURE TESTS

The objectives of temperature tests were to observe and measure the behaviors of the polymers at different temperatures. The two properties examined were gel time and penetration. The gel time is an indicator of both the working time and the final cure time of the polymer. Because all polymers completely filled the narrowest crack width, a penetration test was developed to compare the penetration abilities of the crack sealers when poured over four grades of dry filter sand (Table 5).

The tests were run at 7°C, 13°C, 18°C, 24°C, 29°C, and 35°C (45°F, 55°F, 65°F, 75°F, 85°F, and 95°F) at approximately 50 percent relative humidity by using a programmable environmental chamber. All materials were stored in the chamber 24 hr in advance, and specimens were prepared outside the chamber in less than 20 min so that changes in the temperature of the materials were held to a minimum. Approximately 300 ml of the polymer was mixed for 4 min and was used for the three tests (Component A of E3 required additional stirring before mixing).

Gel Time

A cup containing 20 g of the sealer was checked every 10 to 15 min to determine approximate gel time. For this test *gel time* is defined as the time when the polymer first reaches the consistency of Jell-O and no longer moves down the side of the cup when the cup is tipped. The results of the gel time measurements are reported in

TABLE 3 Flexural Test Results

Product	Crack Width (mm)	Flexure Strength				Flexure Strength Ratio (F/I)	Failure Type %		
		Initial		Final			Bond	Concrete	Polymer
		MPa	(psi)	MPa	(psi)				
U	0.2	6.4	930	6.1	872	94%	11%	87%	2%
	0.5	5.6	817	6.4	922	114%	1%	99%	0%
	0.8	6.6	965	5.3	763	79%	49%	51%	0%
	1.0	5.0	725	5.7	833	118%	27%	73%	0%
	Average	6.0	873	5.9	858	100%	20%	80%	0%
E1	0.2	5.9	853	6.5	938	110%	1%	99%	0%
	0.5	5.6	808	6.0	875	114%	0%	100%	0%
	0.8	5.6	815	6.5	937	119%	2%	98%	0%
	1.0	6.3	915	5.5	942	103%	0%	100%	0%
	Average	5.8	848	5.9	923	112%	1%	99%	0%
E2	0.2	5.3	775	5.8	840	115%	17%	83%	0%
	0.5	5.3	770	6.3	913	123%	23%	77%	0%
	0.8	5.8	848	6.1	883	104%	2%	98%	0%
	1.0	5.0	730	5.7	822	114%	27%	72%	1%
	Average	5.4	781	6.0	865	114%	17%	83%	0%
E3	0.2	5.3	762	6.1	880	118%	2%	98%	0%
	0.5	6.0	867	5.5	805	93%	4%	96%	0%
	0.8	6.0	868	5.4	790	95%	2%	97%	1%
	1.0	6.1	890	5.8	845	95%	2%	97%	1%
	Average	5.8	847	5.7	830	100%	2%	97%	1%
HMWM	0.2	4.7	675	6.0	870	131%	2%	98%	0%
	0.5	6.1	890	6.2	905	102%	0%	94%	6%
	0.8	5.3	775	6.6	957	128%	0%	97%	3%
	1.0	5.7	827	6.1	890	108%	0%	100%	0%
	Average	5.5	800	6.3	909	116%	1%	97%	2%

Table 6 and are illustrated in Figure 3. As the temperature increases, the gel time decreases. U gelled the fastest, completely curing in under 2.5 min at 7° C (45°F). El and HMWM marked the next fastest gel times. E3 required a considerably longer time to gel. E2 took the longest time to gel because it has the unique ability to reach an almost-gel state and to maintain that state for hours before completely gelling. Because time constraints made it difficult to monitor the gel sample for E2 for the necessary length of time, values for the gel times at the colder temperatures are estimates.

Penetration Test

To compare the penetration abilities of the polymers, 40 g of polymer (^{Wt}polymer) was poured over 100 g of dry filter sand in 100-ml cups (^{Wt}sand). Two samples of each of three different gradations of sand were used: MX-65 (very fine), MS-45 (fine), and GX-30 (coarse). FX-50 (very coarse) sand was used in the first test only at 13°C (55°F) and was determined to be ineffective in measuring differences in penetration (Table 6). Once the polymer concrete had cured, the cups were peeled away, the excess sand was brushed off, and the hardened mass was weighed (^{Wt}pc). To compare the penetration abilities of the polymer products the following equations were created:

$$\text{Weight of sand lost} = {}^{Wt}\text{sand} + {}^{Wt}\text{polymer} - {}^{Wt}\text{pc}$$

$$\text{Percent penetration} = \left(\frac{{}^{Wt}\text{sand} - {}^{Wt}\text{sand loss}}{{}^{Wt}\text{sand}} \right) \times 100$$

Plots of the percent penetration versus temperature for all three grades of sand (Figures 4 to 6) illustrate the penetration trends for the products. HMWM penetrated 100 percent of all of the sand samples at all temperatures. E2 was a close second, achieving 100 percent penetration at the higher temperatures. The penetration of El also increased as the temperature increased. U performed completely the opposite with respect to temperature; because of its faster cure rate, the U sealer hardened before maximum penetration potential was achieved. E3 was inconsistent, attaining both very high and very low percent penetration values. The order in mixing the components of E3 may have contributed to the scatter; if Component B was added to the thicker Component A, it did not mix as well as when Component A was added to Component B.

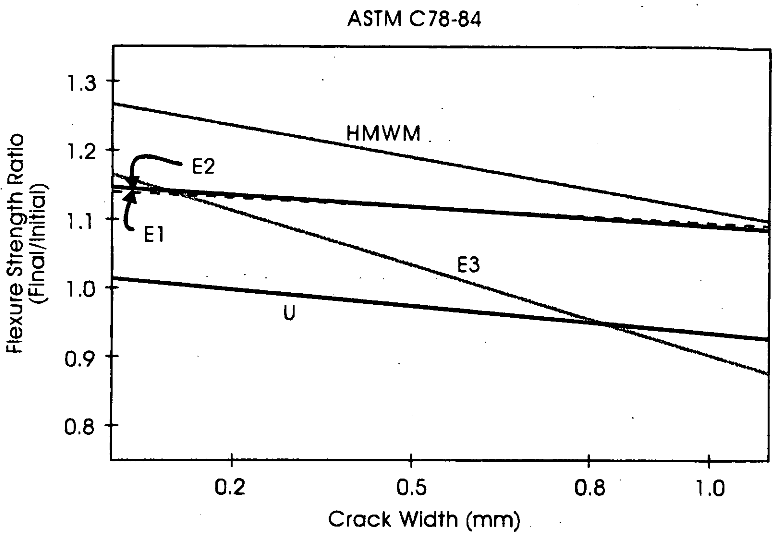

FIGURE 1 **Flexure strength ratio versus crack width.**

SUMMARY OF RESULTS

Overall Effectiveness of Gravity-Fill Polymer Crack Sealers

The results of the tests described here suggest that gravity-fill polymer crack sealers can more than adequately seal cracks in bridge deck concrete. Under ideal conditions the gravity-fill polymer crack sealers completely penetrated 0.2-mm-wide cracks, restored 100 percent or more of the original flexural strengths, were reasonably durable in freeze-thaw testing, and had gel times that decreased as temperature increased. Therefore, all five gravity-fill polymer crack sealers can be fast, effective, durable, and practical repair materials, although some materials perform better in certain tests.

Effects of Crack Width and Treatment Temperature

Temperature and crack widths influenced performance based on individual products. HMWM is effective under a variety of conditions. E2 also performs well for all crack sizes and temperatures; however, the gel times are extremely long at the colder temperatures. E1, E3, and U all appear to seal narrow cracks better. E1 penetrates better at higher temperatures, no definite effect of tempera-

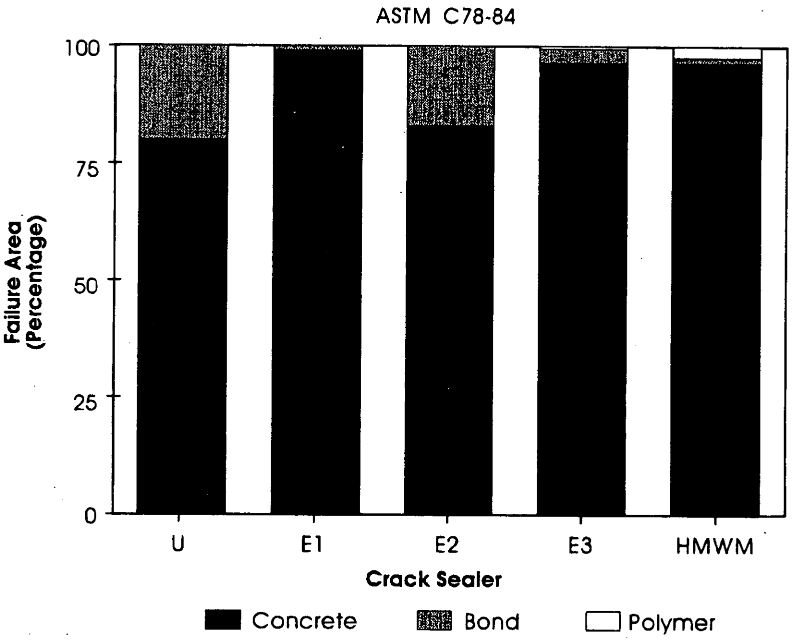

FIGURE 2 **Failure mode of new crack.**

TABLE 4 Freeze-Thaw Test Results

Product	Crack Width (mm)	Flexure Strength Initial		Flexure Strength Final		Flexure Strength Ratio (F/I)	Failure Type %		
		MPa	(psi)	MPa	(psi)		Bond	Concrete	Polymer
U	0.2	4.8	700	1.2	170	24%	100%	0%	0%
	0.5	4.9	710	0.3	45	6%	100%	0%	0%
	1.0	4.1	600	0.3	41	7%	100%	0%	0%
	Average	4.6	670	0.6	85	12%	100%	0%	0%
E1	0.2	4.8	700	3.7	530	76%	0%	100%	0%
	0.5	4.4	635	3.5	515	81%	50%	50%	0%
	1.0	5.1	745	2.8	410	55%	70%	30%	0%
	Average	4.8	693	3.3	485	71%	40%	60%	0%
E2	0.2	4.6	665	3.1	445	67%	15%	85%	0%
	0.5	4.6	670	2.6	380	57%	20%	80%	0%
	1.0	4.1	600	2.7	390	65%	0%	100%	0%
	Average	4.4	645	2.8	405	63%	12%	88%	0%
E3	0.2	4.4	645	2.5	370	57%	30%	70%	0%
	0.5	4.3	630	0.1	11	2%	100%	0%	0%
	1.0	4.5	660	1.0	140	21%	90%	10%	0%
	Average	4.4	645	1.2	174	27%	73%	27%	0%
HMWM	0.2	4.3	620	3.0	440	71%	3%	95%	2%
	0.5	4.4	640	3.3	475	74%	0%	100%	0%
	1.0	4.9	710	2.6	375	53%	0%	100%	0%
	Average	4.5	657	3.0	430	66%	1%	98%	1%

Freeze Thaw: 480 cycles

ture on penetration is evident for E3, and U penetrates the best at lower temperatures.

Critiques of Individual Products

The strengths, weaknesses, and best conditions for use are summarized for each gravity-fill polymer crack sealer product tested.

U

Description U is in a category of its own. It cures incredibly fast, it has almost no odor, and the application procedure is very user friendly. However, its ability to penetrate narrow cracks at high temperatures, seal large cracks effectively, and withstand the stresses of freezing-thawing is somewhat less than those of the other products.

TABLE 5 Sand Grades Used in Penetration Tests

Sand Product[a]	% Passing Sieve Sizes #30	#100	#140
MX-65	99.5%	19.9%	5.4%
MX-45	94.9%	3.5%	1.0%
GX-30	94.5%	2.0%	0.0%
FX-50	29.3%	0.0%	0.0%

[a] donated by Foster Dixiana, P. O. Box 2005, Columbia, South Carolina 29202

TABLE 6 Temperature Test Results

	Temp.		Gel Time			% Penetration in Sand[a]			
Product	°C	°F	(hrs)	(min)	(sec)	MX-65	MX-45	GX-30	FX-50
U	7	45	--	2	30	75	91	95	--
	13	55	--	2	0	63	88	--	100
	18	65	--	1	15	60	89	96	--
	24	75	--	0	45	55	82	84	--
	29	85	--	0	35	58	66	86	--
	35	95	--	0	30	51	57	61	--
E1	7	45	10	--	--	53	81	92	--
	13	55	5	--	--	59	85	--	91
	18	65	2	50	--	73	90	96	--
	24	75	1	45	--	68	82	92	--
	29	85	1	--	--	68	91	94	--
	35	95	--	50	--	74	98	92	--
E2	7	45	19	--	--	87	99	100	--
	13	55	14	30	--	94	94	--	99
	18	65	8	30	--	99	99	100	--
	24	75	6	--	--	99	99	100	--
	29	85	4	--	--	100	100	100	--
	35	95	1	30	--	100	100	100	--
E3	7	45	15	30	--	67	93	84	--
	13	55	11	30	--	55	83	--	96
	18	65	5	--	--	67	95	88	--
	24	75	2	--	--	71	95	81	--
	29	85	2	--	--	79	79	89	--
	35	95	--	50	--	62	72	85	--
HMWM	7	45	10	30	--	100	100	100	--
	13	55	5	30	--	100	100	--	100
	18	65	3	--	--	100	100	100	--
	24	75	1	--	--	100	100	100	--
	29	85	--	40	--	100	100	100	--
	35	95	--	30	--	100	100	100	--

[a] Sands in order of decreasing fineness (left to right).

Application For repairs for which the quickness of repair is critical U is appropriate. It is good for small cracked sections where leaking may be a problem and sealing the underside of the deck is not practical.

E1

Description E1 performed satisfactorily in all tests. Desirable qualities include its low cost, easy mix ratios, low percent bond failure, high freeze-thaw durability, and rapid gel times. However, E1 had a relatively strong odor.

Application E1 can be used for low-budget projects for which the quickness of repair and durability are desirable. E1 works best on small cracks at higher temperatures.

E2

Description E2 is suitable for treating cracks under a variety of conditions. Tests show that E2 has an outstanding capacity to penetrate the full depth of narrow cracks, restore the strength of the concrete, and resist freeze-thaw cycling. Potential drawbacks of the product include extremely long gel times, high cost, and possible

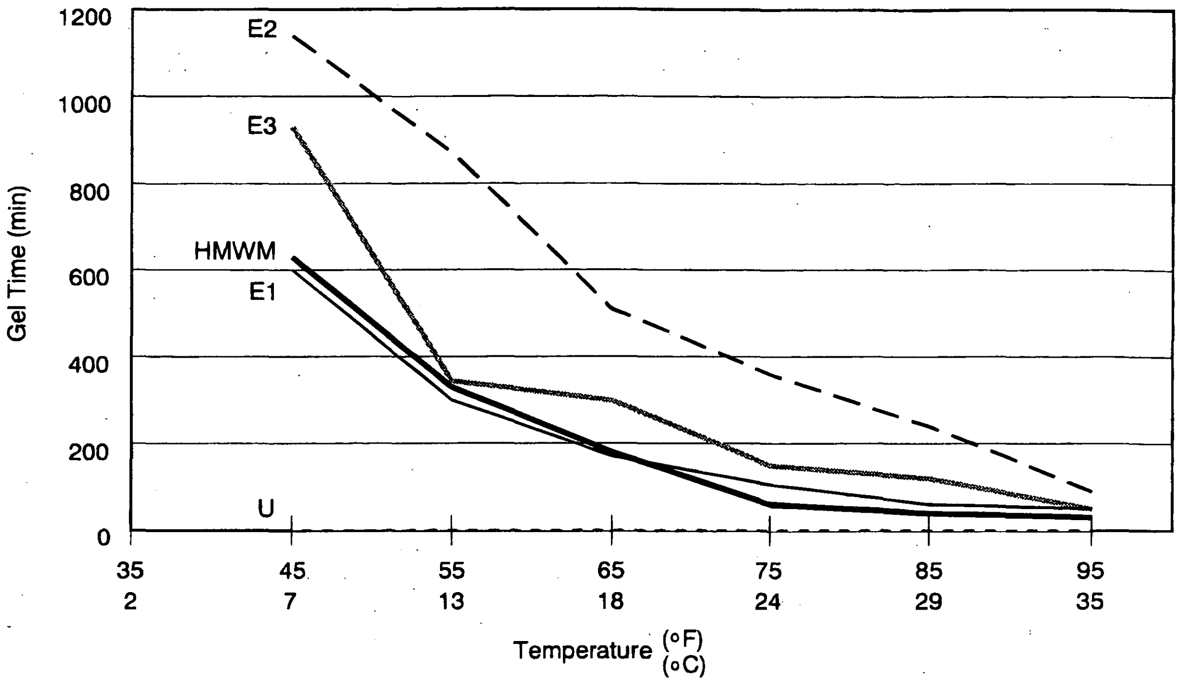

FIGURE 3 Gel time versus temperature for gravity-fill polymer crack sealers.

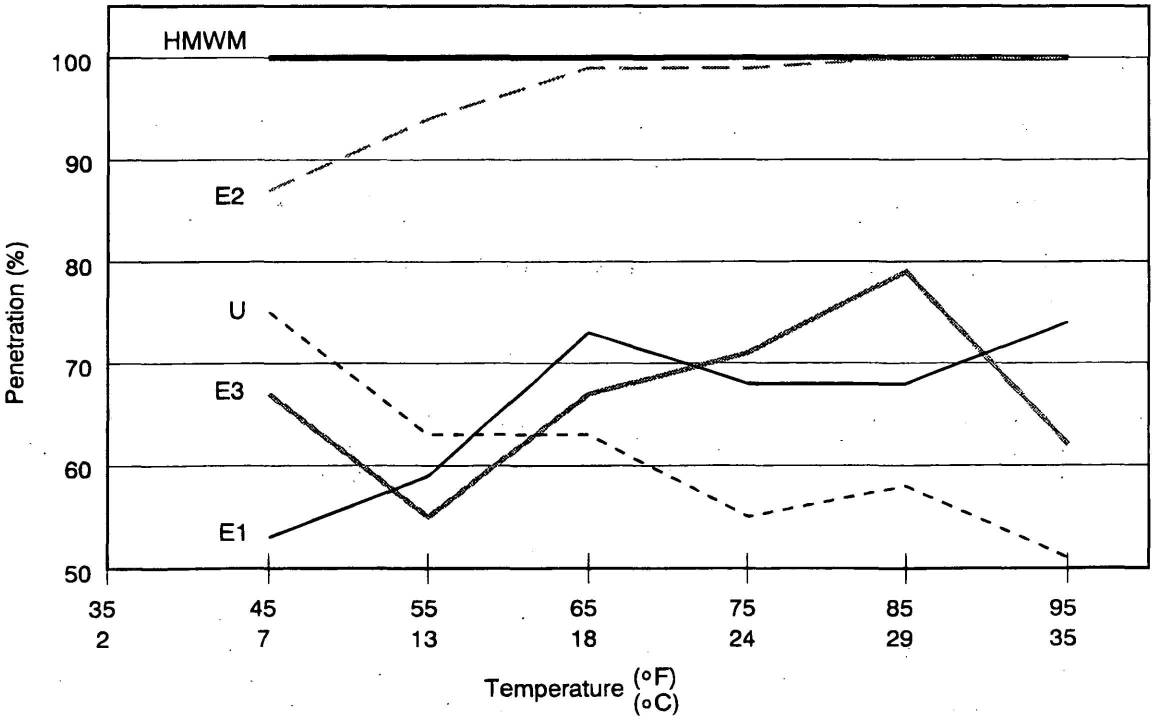

FIGURE 4 Percent penetration versus temperature: MX-65 (very fine).

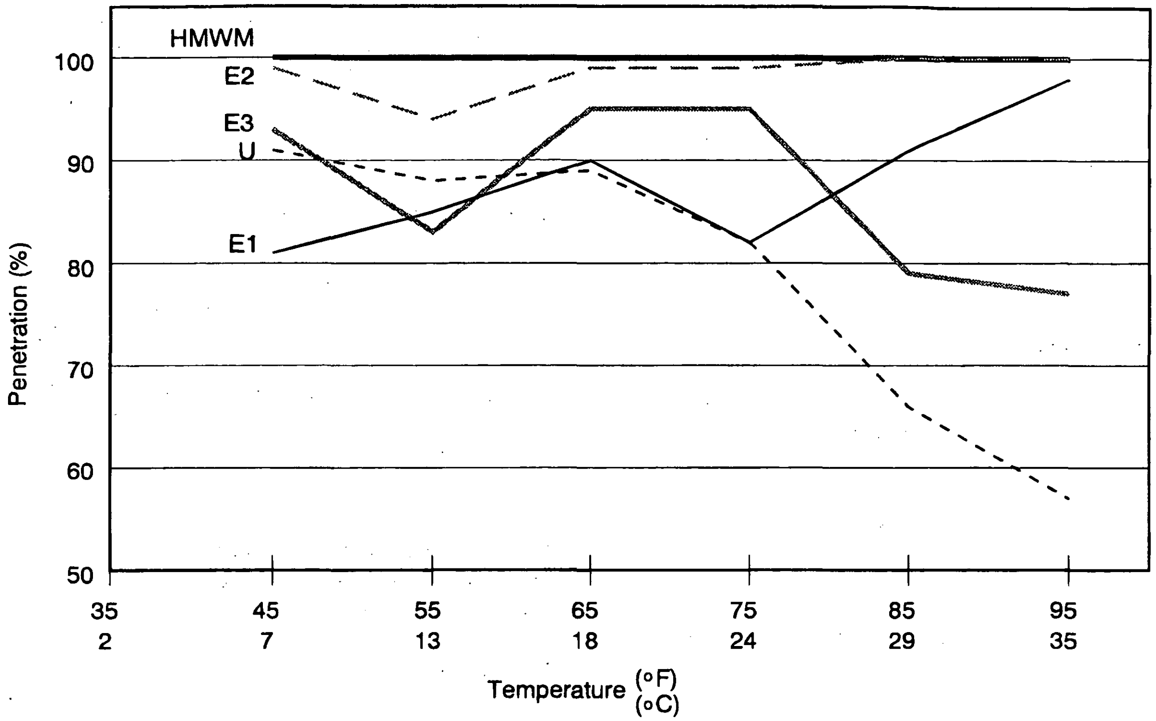

FIGURE 5 Percent penetration versus temperature: MX-45 (fine).

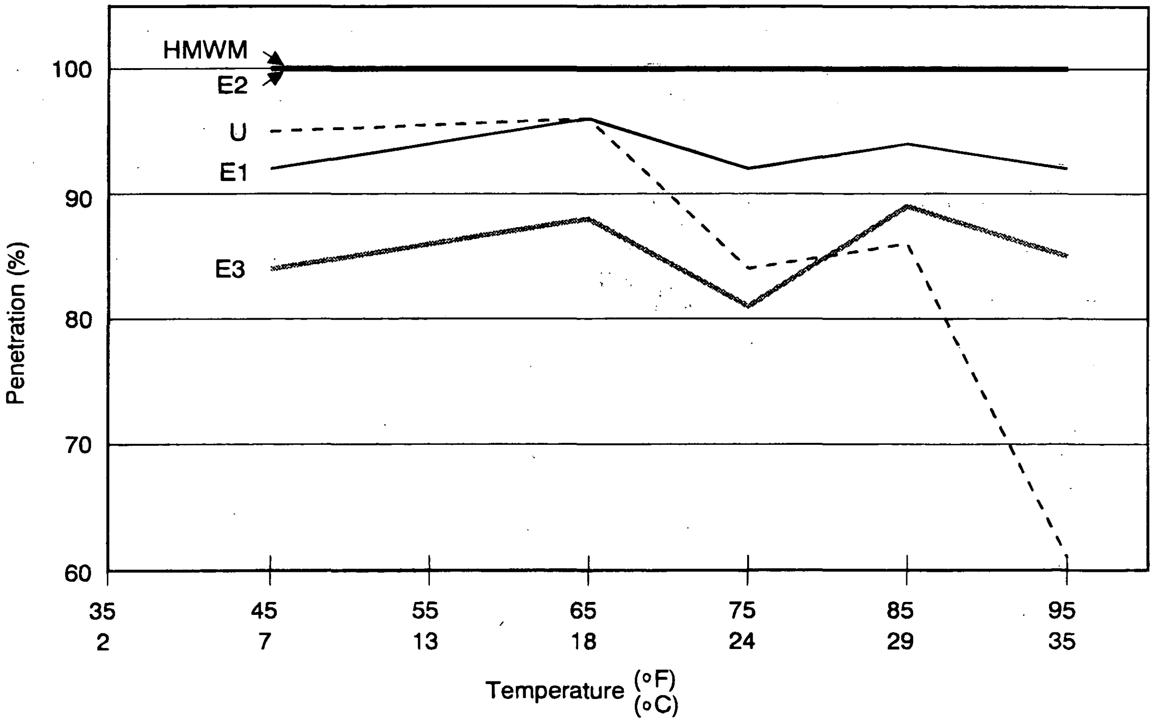

FIGURE 6 Percent penetration versus temperature: GX-30 (coarse).

negative color. However, the components are easy to mix, have a mild odor, and are very safe to use.

Application E2 can be applied to projects for which quality and durability (not quickness of repair) are critical factors. It is excellent for hairline cracks and is ideal for repairs where odor is a concern.

E3

Description E3 performed satisfactorily in most tests. It achieved a low bond failure rate and a good flexural strength ratio and is relatively inexpensive. Because of its long gel times and the wetting additives claimed to be in the product, E3 typically penetrated better at low temperatures, but its performance was scattered. The difficulty in mixing exact proportions is the most probable cause for the variation in results; therefore, further testing is recommended. Its inability to withstand freeze-thaw cycling is a matter of concern.

Application E3 can be used for a low-budget temporary project for which sealing is more critical than fast repair times.

HMWM

Description HMWM outperformed the other products tested. It achieved an outstanding flexural strength ratio and low percent bond failure even after freeze-thaw cycling. It gelled very quickly and penetrated 100 percent of the finest sand at the lowest temperature. Despite these strengths the smell of HMWM is extremely pungent and can explode if the three components are mixed in the wrong order. Also, the mixing ratios are relatively complicated, and its low viscosity may cause problems of leaking to other areas.

Application HMWM is good for all types of projects or for projects for which low budget, time of repair, and durability are all critical factors. It is effective at a temperature range of between 4 and 38°C (40 and 100°F). It is excellent for use on hairline cracks; however, leaking may be a problem. It should be used for projects away from large populations of people in well-ventilated areas.

COMPARISON OF PRODUCTS

A comparative evaluation of the products is provided in Table 7. When equal weight is given to each of the nine properties the total points are similar for the five products and E1, E2, and HMWM are ranked 1, 2, and 3, respectively. When only the performance of the products is considered (last four properties in Table 7) HMWM and E2 are clearly ranked 1 and 2, respectively, E1 is clearly third, and E3 and U are fourth and fifth, respectively.

VIRGINIA DEPARTMENT OF TRANSPORTATION SPECIAL PROVISIONS FOR GRAVITY-FILL CRACK SEALING

I. Description

This work shall consist of preparing concrete cracks and treatment with a polymer crack sealer.

II. Materials

E1, E2, E3, HMWM, U (from approved products list)
Gel time, 50 ml, maximum at 24°C. . . . . 6 hr
Tensile strength, minimum at 24°C (ASTM D638) . . . 10MPa (1,500 lb/in.^{2})
Sand penetration, MX-45, minimum at 24°C . . . . 80 percent
A Material Safety Data Sheet (MSDS) shall be furnished with the material to be used on project.

TABLE 7 Comparative Evaluation of Crack Sealers

Product	U	E1	E2	E3	HMWM
Easy to mix	2	1	1	3	5
Odor	1	3	2	3	5
Safety	1	1	1	1	4
Cost	5	1	5	3	3
Cure Time	1	2	5	3	2
Flexural Strength	2	1	1	2	1
Freeze Thaw	5	2	2	4	2
Penetration 7-24°C	4	4	2	4	1
Penetration 24-35°C	5	3	1	3	1
Total Points	26	18	20	26	24
Rank (All Properties)	4	1	2	4	3
Rank (Performance)	5	3	2	4	1

III. Surface Preparation

The concrete surface must be dry! Air blast cracks to remove dust, dirt, and debris with oil-free compressed air.

IV. Application

The concrete surface temperature shall not be less than 13°C (55°F) when the gravity-fill crack sealer is applied. The resin should be applied at the lowest temperature of the day when the cracks are open the most (approximately) 1 a.m. to 9 a.m. Before placing the polymer, dry, no. 50-sieve-size silica sand should be placed in cracks that are wider than 1 mm. The gravity-fill polymer crack sealer should be applied directly to the cracks. Allow a few minutes for the material to seep down into cracks, and then make additional applications until the cracks are filled. Material may be spread over designated cracked area, and material shall be worked into the cracks with a broom. Excess material not worked into cracks should be brushed off the surface before the polymer sets up. Resin shall be applied in a sufficient quantity and number of applications to fill the cracks. An application rate of 124 ml/m or 407 ml/m^2 (1 gal per 100 linear ft or 100 ft^2) is usually adequate. Application of crack sealers shall be done before grooving concrete decks.

V. Limitations of Operations

The Contractor shall plan and prosecute the operations in such a manner as to protect persons and vehicles from injury or damage. Armored joints shall be covered, scuppers shall be plugged, and cracks shall be sealed underneath or other protective measures shall be used in such a manner as to protect traffic, waterways, and bridge components. In the event that material or solvent harms the appearance of bridge components, removal will be required as determined by the Engineer. A sealed surface shall not be opened to traffic until grooving is complete. Grooves shall not be cut until the polymer crack sealer has cured a minimum of 10 times the gel time.

VI. Method of Measurement

When practical as determined by the Engineer crack sealing will be measured in linear meters (feet). Otherwise, crack sealing will be measured in square meters (yards) of cracked surface.

VII. Basis of Payment

Crack sealing will be paid for at the contract unit price bid per linear meter (foot) or square meter (yard), which price shall be full compensation for preparing cracks, furnishing and applying the resin, protection of waterways and traffic, and cleaning up and for all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under the following:

Pay Item	*Pay Unit*
Crack sealing	Linear meter (foot)
Crack sealing	Square meter (yard)

CONCLUSIONS

1. Gravity-fill polymer sealers can seal cracks ranging in width from 0.2 to 1.0 mm.
2. All five products meet current Virginia Department of Transportation specifications.
3. HMWM performed the best, but it has a strong, pungent odor and possible dangerous mixing process.
4. E2 performed almost as well as HMWM but has a long cure time and a high cost.
5. E1 did not perform as well as HMWM or E2 but may be the product of choice when all factors are considered.
6. E3 is ranked fourth because of its low durability and its difficult-to-use mix ratios.
7. U is ranked last, despite the very efficient application method, low odor, and incredibly fast cure times, because it performed the worst in all the tests. Also, it penetrates best at temperatures below 24°C.

RECOMMENDATION

Crack repairs on bridge deck concrete are recommended as follows:

- Preplace sand in cracks with a width greater than 1 mm.
- Place monomers prior to 9:00 a.m. and during colder weather when cracks are widest.
- Cracked concrete surfaces should be dry and sound.
- Air blast or water blast cracks before placing the monomers.
- Broom monomers into the crack until the crack is full.

REFERENCES

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